

IMPORTANCE OF GEODETICALLY CONTROLLED TOPOGRAPHY TO CONSTRAIN RATES OF VOLCANISM AND INTERNAL MAGMA PLUMBING SYSTEMS. L. S. Glaze¹, S. M. Baloga², J. B. Garvin¹, and L. C. Quick^{1,3}, ¹NASA Goddard Space Flight Center (8800 Greenbelt Road, Greenbelt, MD 20771, Lori.S.Glaze@nasa.gov, James.B.Garvin@nasa.gov), ²Proxemy Research (20528 Farcroft Lane, Gaithersburg, MD 20882, steve@proxemy.com), ³Oak Ridge Associated Universities (Lynnae.C.Quick@nasa.gov).

Session: From orbit.

Target: Large lava flows, e.g., flank flows on Sif Mons (22°N, 352.4°E) and Sapas Mons (8.5°N, 188.3°E), shown in Figure 1.

Science Goal(s): Investigation of lava flow deposits is a key component of Investigation II.A.1 in the VEXAG Goals, Objectives and Investigations. Because much of the Venus surface is covered in lava flows, characterization of lava flow emplacement conditions (eruption rate and eruption duration) is critical for understanding the mechanisms through which magma is stored and released onto the surface as well as for placing constraints on rates of volcanic resurfacing throughout the geologic record preserved at the surface.

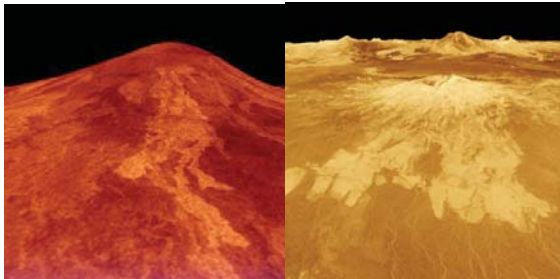


Figure 1. Examples of lava flows (bright lobate features in the foreground) on the flanks of Sif Mons (22°N, 352.4°E) on the left, and Sapas Mons (8.5°N, 188.3°E) on the right.

Discussion: Over the last 15 years, Venus has fallen well behind Mars in our understanding of how magma is transported to, and emplaced onto, the surface. Much of the new insights for Mars volcanism have been gained through theoretical modeling studies of martian lava flows [1-8]. The fundamental data that have allowed this progress to be made are the precise, geodetically referenced topography from the Mars Orbiter Laser Altimeter (MOLA). The precise geolocated MOLA topographic data set was established through a combination of precision orbit determination and detailed crossover analysis to define the location of each elevation point in x-y-z coordinates, with every point referenced to the center of mass of the planet. Glaze et al. [1] showed that with center-of-mass-referenced topographic data, precise cross-flow profiles from multiple orbiter passes could be combined to precisely reconstruct the down flow topographic shape of the

lava flows on Mars (Figure 2). The increased quality of topographic data for Mars has driven a rapid increase in the capabilities of lava flow emplacement models. As an example, the most complex analytical model [8] includes formation of levees through two end-member processes during emplacement: construction as the flow front passes and continued growth along the flow after the front has passed. This level of complexity is not even conceivable for Venus lava flow modeling studies because topographic data of sufficient quality do not exist.

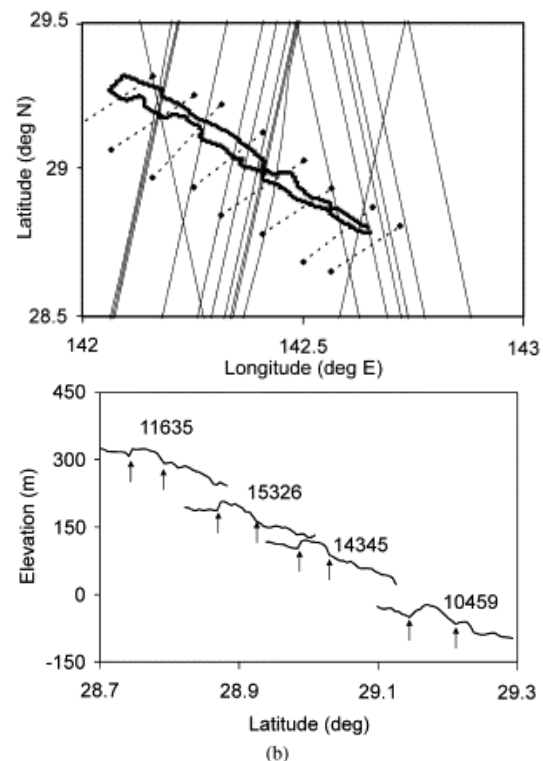


Figure 2. Top figure shows the outline of a lava flow in Elysium Planitia that is ~150 km long and ~5 km wide (on average) along with MOLA ground tracks (solid black lines) that cross the flow. Lower figure shows topographic profiles across the same lava flow for several of the MOLA ground tracks. These data were used by [1] to build up a longitudinal lava flow thickness profile for this lava flow and then used to constrain theoretical models of emplacement.

For Mars, multiple studies [1-8] have demonstrated that estimates of volume eruption rates and eruption

durations are dependent not just on the horizontal dimensions of a lava flow (length and width), but critically depend on the down flow “shape” of the lava flow. The shape of the upper surface of a lava flow (e.g., concave up vs. concave down) provides a great deal of information on the bulk rheologic behavior of the lava. Further, the rate at which a lava flow thickens as a function of distance from the vent is also a key indicator of how well insulated a flow was during emplacement and of how the bulk viscosity increased over time and distance from the vent (which is a record of the cooling history).

The ability to reconstruct the down flow shape (thickness as a function of distance from the source) requires substantially more than simply determining relative thickness of a lava flow at some point along the flow. Such relative measurements can easily be made from stereo topography, or in the case of radar, from Interferometric Synthetic Aperture Radar (InSAR) derived topography. However, there are fundamental issues associated with topography derived from both stereo SAR or InSAR techniques, including layover effects due to off-nadir directionality of SAR imaging, and the fact that two adjacent orbital passes are not uniquely referenced to the center of mass of the planet. As a result, individual topographic information derived from different orbital passes cannot be reliably used to reconstruct the down flow shape of lava flows, or other large features that extend beyond a single image scene.

In the Mars examples referenced above, the gridded topographic data were generally not used because of the interpolation between data points [1]. But the individual MOLA ground shots along the orbit ground tracks were shown to be extremely useful (e.g., Figure 2). Recent modeling work [8] has used topographic thickness data to estimate down-flow crustal thicknesses of 9 – 23 m for six large lava flows in the Tharsis province. Associated emplacement durations for these six flows range from 1 year to 10 years, with corresponding viscosities of $10^5 - 10^6$ Pa s. Volume effusion rates for these six flows were estimated by [8] to be 25 – 840 m³/s, analogous to eruption rates observed on Earth. This tells us that the internal magma plumbing systems in the Tharsis region on Mars are very similar to Earth. The primary difference is the overall volume of the individual lava flow units.

On Venus, the large lava flows and flow fields lack sufficient topographic data for any type of similar quantitative modeling. For example, within the low-resolution Magellan SAR images, it is very difficult to distinguish one flow from another when adjacent flows have similar backscatter characteristics. This can be addressed at some level with higher resolution SAR imaging that may be able to distinguish small-scale

(meters) differences between adjacent flow units. Spatial resolutions required are on the order of 10-30 m. More importantly, center-of-mass-referenced topographic information with a precision of < 10 m is required to characterize both the cross-flow and along flow thickness profiles. Interestingly, for this application, horizontal spatial resolution is less important. As long as each topographic point is georeferenced to the center of mass of the planet, the only spatial requirement is that there be sufficient topographic samples along track to have a good characterization of the cross flow shape of a lava flow (typically several points across a flow). For a lava flow that is a few kilometers across, the horizontal sampling requirement is ~ 300 m (note that MOLA ground shots had a point spacing of 330 m).

It is critical that future orbiting radar missions include capabilities for radar imaging at horizontal resolutions significantly greater than Magellan and that any topographic data sets generated by such missions be geodetically referenced to the center of mass of the planet. Radar altimetry with along-track spacing of ~ 300 m and vertical precision of < 10 m would provide sufficient data to make great progress in better understanding the conditions under which the lava flows that cover the surface of Venus were emplaced.

References: [1] Glaze L. S. et al. (2003) *Icarus*, 165, 26-33. [2] Baloga S. M. et al. (2003) *JGR*, 108 (E7), 5066. [3] Rowland S. K. et al. (2004) *JGR*, 109 (E10010). [4] Glaze L. S. and Baloga S. M. (2006) *JGR*, 111 (E09006). [5] Glaze L. S. and Baloga S. M. (2007) *JGR*, 112 (E08006). [6] Hiesinger et al. (2007) *JGR*, 112 (E05011). [7] Baloga S. M. and Glaze L. S. (2008) *JGR*, 113 (E05003). [8] Glaze L. S. et al. (2009) *JGR*, 114 (E07001).